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KRYPTON-85 POWERED LIGHTS FOR AIRFIELD APPLICATION.(U)

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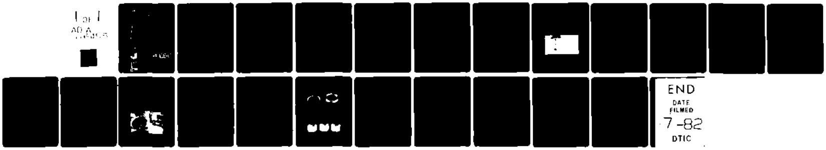

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KRYPTON - 85 POWERED LIGHTS FOR AIRFIELD APPLICATION

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NOVEMBER 1981

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Airfield lighting is complex in its requirements for lights of various intensities and colors. Some applications such as taxiway lights, information signs, and combat situations may be served by lights of relatively low intensity. They should meet criteria such as energy efficiency, little or no dependence upon batteries or generators, low maintenance, and rapid deployment. Lights powered with krypton-85 provide some of these advantages. This report summarizes an effort to develop krypton-85 powered airfield lighting. Light is produced when beta rays from krypton-85 excite

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) a phosphor. Phosphors selected produced blue, red, and yellow-green light. Field testing of the lights was sufficiently encouraging to continue development in a follow-on effort.

PREFACE

This report presents the summary of effort by the Radioisotope Technology Group of Oak Ridge National Laboratory, Post Office Box X, Oak Ridge Tennessee 37830 in a joint program sponsored by the Department of Energy and the U. S. Air Force under Interagency Agreement 40-1049-79 to develop krypton-85 powered lights for airfield application. The report covers the period October 1979 through September 1980. The monitoring office for the U. S. Air Force was the Air Force Engineering and Service Center, Tyndall Air Force Base, Florida 32403.

This report has been reviewed by the Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nations. This report has been reviewed and is approved for publication.

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TABLE OF CONTENTS

Section	Title	Page
I	INTRODUCTION	1
II	BACKGROUND AND THEORY	3
	Background	3
	Theory	4
III	MEASUREMENT OF LIGHT OUTPUT	8
	Light Source Design	9
	Shield and Light Pipe	10
	Health and Safety	12
IV	CONCLUSION	15
	REFERENCES	17

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LIST OF FIGURES

Figure	Title	Page
1	Cone-Shaped Krypton-85 Light Unit.	1
2	Photopic Response of Human Eye to Light.	5
3	Light Chamber Used to Make Relative Light Intensities from Krypton-85 Light Sources	8
4	Krypton-85 Light Source in Reflector	11
5	Complete Assembly of Three Krypton-85 Lights	11

LIST OF TABLES

Table	Title	Page
1	Immersion Doses Resulting from Various Accident Scenarios.	14

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SECTION I

INTRODUCTION

Airfield lighting is complex in its requirements for lights of various intensities and colors. Some applications such as taxiway markers, information signs, and certain combat situations, may be served by lights of relatively low intensity if they meet criteria such as energy efficiency, little or no dependance upon batteries or generators, low maintenance, and rapid deployment. Lights powered with krypton-85 (^{85}Kr) provide some of these advantages. Thus, a program to develop lights to meet specific requirements was started in a joint program by the U. S. Air Force and the Department of Energy (DOE), and eight lights were fabricated for testing by actual observation under airfield conditions. Light is produced in the units when the beta rays from ^{85}Kr excite a phosphor. The phosphor is prepared in granular form and placed inside of a 40-in.-long quartz tube (FIGURE 1). The tube is coiled in cone fashion to fit into a lead-shielded hemispherical reflector. The reflector provides shielding for the gamma radiation emitted from the 10 curies of ^{85}Kr gas sealed into the tube with the phosphor. Phosphors were selected to produce blue, red, and yellow-green light. The light from this sealed light source was transmitted out of the shield through a 6-in.-diam, 14-in.-long lucite light pipe domed at the top for light emission.

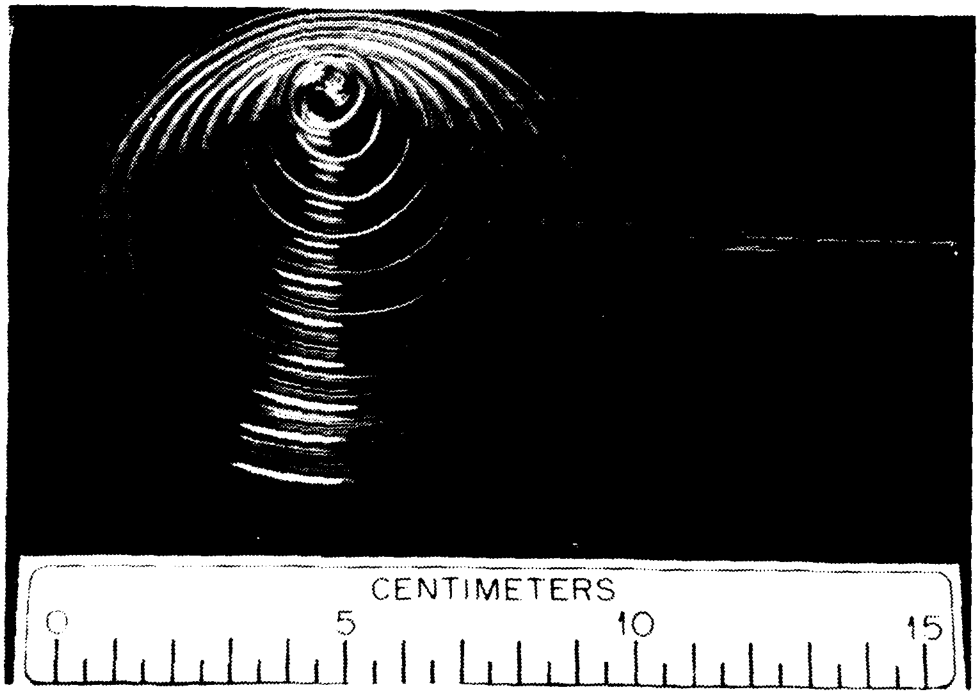

Figure 1. Cone-Shaped Krypton-85 Light Unit

The lights were deployed in various arrays at Andrews Air Force Base. This Base has a high level of ambient light at night due to sky-shine from the city of Washington, D. C. and from the background lighting on the air base itself. Night-time observations under these conditions by helicopter pilots provided an evaluation of the distance from which the lights could be acquired; this acquisition distance ranged from 4,000 to 6,000 ft, depending upon the observer.

This report discusses the basic concepts of radionuclide-powered lights, the R&D program carried out, and fabrication constraints involved in the production of the experimental lights tested.

SECTION II

BACKGROUND AND THEORY

BACKGROUND

The use of radiation from radionuclides in combination with phosphors to produce visible light has been known for many years. Early use of radium mixed with zinc sulfide phosphors provided self-illuminated clock dials. The military has used light-emitting paints for aircraft dial illumination, mine field markers, and gun sight illumination routinely. Industrial uses involve exit signs and light standards in the photographic industry. Advantages in using radionuclide-powered lights are:

(1) The complete independence from an electrical power source makes their use of interest in areas where electrical power is either unavailable, costly, or time consuming to install.

(2) Radioisotope-excited light sources are not subject to power failures or interruptions.

(3) Since the units do not "burn out", maintenance is virtually eliminated.

(4) Supply problems arising from short shelf-life and component replacement, such as batteries and bulbs, can be greatly reduced.

(5) Self-luminous sources can function under many types of severe environmental conditions, such as at temperatures lower than -70°F.

The radionuclides krypton-85 (^{85}Kr) and tritium (^{3}H), both of which are in gaseous form under ordinary conditions, are useful for the production of low-level lighting. Krypton-85 is produced during the fission of uranium in nuclear reactors. It is, therefore, byproduct to the nuclear defense programs and to the production of electricity by nuclear power plants. Tritium is a primary product of the nuclear defense programs, but also finds many beneficial civilian applications in health care, research, petroleum production, and industrial production. The effort described in this report is concerned with ^{85}Kr-activated lights, however, in general a radionuclide candidate for the production of lights should have the following characteristics.

(1) The radioisotope should have a half-life of at least five years.

(2) The radioisotope should represent a minimal biological hazard.

(3) The radioisotope should emit little or no gamma radiation.

(4) The maximum beta energy should be an optimum with respect to maximum obtainable brightness and minimum phosphor damage.

Both beta and alpha radiation are useful in lighting applications. Practical applications, however, are confined to beta emitters because of their availability and low order of hazard.

THEORY

The luminescent phenomenon can be visualized in a usual semiconductor band theory wherein a valence band electron is excited into the conduction band. On subsequent return to the lower energy or valence state, visible radiation is emitted as required by energy conservation. This implies a band gap on the order of 1 to 4 ev, or in the 4,000 to 7,000 Å region. The phosphors of concern most generally have trapping levels in the forbidden gap that allows persistence of light emission. Generally, it is assumed that these trapping levels capture electrons that have been raised to the conduction band. As a valence-trap transition is forbidden, the electron must be subsequently raised to the conduction band (possibly by thermal activity) and subsequently drop to the valence band and emit its characteristic radiation. It is also possible for the conduction band to trapping level transitions to emit visible radiation as confirmed by the fact that a number of phosphors emit several wavelengths. It is noted that thermal effects smear the forbidden gap and trapping levels over an energy region so that the emitted radiation is not monochromatic. The complete analysis of this phenomenon is quite complex and not well understood. Suffice to say that many compounds exhibit phosphorescence under beta radiation and those most conventionally used are composed of elements shown in the periodic table as group IIB-VIA with closely controlled impurities of the IB and VA groups.

Human vision consists of the combined response of two types of sensing elements in the retina of the eye. The two types are rods and cones which are present in varying ratios over the area of the retina; however, there is a small high-resolution area near the center of the visual field (the fovea centralis) which contains only cones. The cones are responsible for the sensation of color, but the threshold for stimulation of the cones (photopic vision) is nearly ten times higher than that required for stimulation of the rods (scotopic vision) by low intensity blue light. Thus, at low brightness, dark-adapted (full dark acquisition requires approximately 45 min) extra-foveal vision is extremely sensitive in perceiving blue light, but without the perception of color. The peak of the scotopic luminosity function is at 507 nm, with an absolute conversion factor of 1746 scotopic lumens per watt (ℓm/W); the peak of the photopic luminosity function is at 555 nm, with an absolute conversion factor of 680 ℓm/W. The scotopic function is considered representative of eyes under 30 years old and for viewing at angles greater than 5° from the fovea. The human eye response is shown in FIGURE 2.

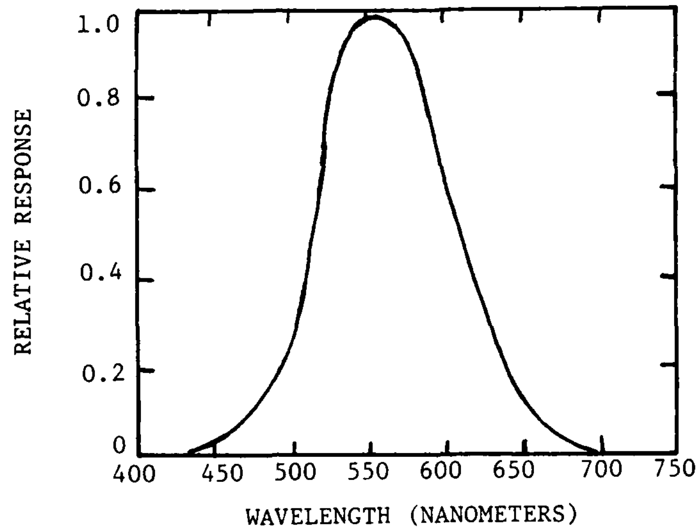

FIGURE 2. Photopic Response of Human Eye to Light

The limit of perception of a point source of white light is about 1 to 2×10^{-7} £m/meter^2 for photopic vision and of the order of 4×10^{-9} £m/meter^2 for scotopic vision. Thus, a distant white light may be invisible if looked at directly, but may "flare" if the eye is directed five or more degrees to one side of it. For scotopic vision, the bluer the light, the lower the threshold. The sensation of light (not color) begins for blue light at approximately 4×10^{-10} £m/meter^2 for steady sources against a black background. This physiological information provides the maximum possible acquisition distance for isotopic light sources.

Assuming 0.67 MeV (yield 99.6%)[1] as the average beta energy from ^{85}Kr, it can be shown that:[2]

---

[1]C. M. Lederer, J. M. Hollander, and I. Perdman. Table of Isotopes. (New York, John Wiley and Sons, Inc., 6th Edition, 1967).

[2]I. Kaplan. Nuclear Physics. (Reading, Massachusetts, Addison-Wesley Publishing Company, Inc., Fourth Edition, July 1958).

$$1 \text{ curie } {}^{85}\text{Kr} = \left(3.7 \times 10^{10} \frac{\beta}{\text{sec}}\right)\left(\frac{0.67}{3} \frac{\text{MeV}}{\beta}\right)(0.996)\left(1.6 \times 10^{-6} \frac{\text{erg}}{\text{MeV}}\right) \cdot$$

$$\left(10^{-4} \frac{\text{milliwatts}}{\text{erg/sec}}\right)$$

$$\cong 1.3 \frac{\text{milliwatts}}{\text{curie}}$$

Similarly, for other candidate isotopes:

Strontium-90	≅ 3 milliwatts/curie
Promethium-147	≅ 0.4 milliwatts/curie
Tritium	≅ 0.04 milliwatts/curie

If 100% conversion of beta energy to blue light can be obtained, and assuming a point source, we can reach a maximum scotopic luminous flux of:

$$\left(1.3 \times 10^{-3} \frac{\text{W}}{\text{Ci } {}^{85}\text{Kr}}\right)\left(1746 \frac{\mathcal{L}\text{m}}{\text{W}}\right)(0.6)(30 \text{ Ci } {}^{85}\text{Kr}) = 41\ \mathcal{L}\text{m or } 1.36\ \mathcal{L}\text{m/Ci } {}^{85}\text{Kr}\ ,$$

and a maximum photopic luminous flux of:

$$\left(1.3 \times 10^{-3} \frac{\text{W}}{\text{Ci } {}^{85}\text{Kr}}\right)\left(680 \frac{\mathcal{L}\text{m}}{\text{W}}\right)(0.06)(30 \text{ Ci } {}^{85}\text{Kr}) = 1.6\ \mathcal{L}\text{m or } 0.053\ \mathcal{L}\text{m/Ci } {}^{85}\text{Kr}\ ,$$

where the 0.6 and 0.06 factors are the efficiencies for 460 nm light on the scotopic and photopic luminosity functions, respectively. (30 Ci ^{85}Kr is the maximum amount of ^{85}Kr allowed in a light source meeting ANSI standards for ^{85}Kr lights.)

As previously stated, the scotopic limit of perception for blue light is about 4×10^{-10} $\mathcal{L}$m/meter^2, while the corresponding photopic limit is approximately 1×10^{-7} $\mathcal{L}$m/meter^2. This permits us to solve for the limiting distance of perception in the two modes of vision:

Scotopic: $$\frac{41\ \mathcal{L}\text{m}}{4\pi\ r^2} = 4 \times 10^{-10} \frac{\mathcal{L}\text{m}}{\text{m}^2}$$

or

$$r = \sqrt{\frac{41 \times 10^{10}}{16\ \pi}} = 9 \times 10^4 \text{ m} = 2.96 \times 10^5 \text{ ft}$$
$$= 56.1 \text{ mi}$$

Photopic: $$\frac{1.6\ \mathcal{L}\text{m}}{4\pi\ r^2} = 1 \times 10^{-7} \frac{\mathcal{L}\text{m}}{\text{m}^2}$$

or

$$r = \sqrt{\frac{1.6 \times 10^7}{4\pi}} = 1128 \text{ m} = 3702 \text{ ft}$$
$$= 0.7 \text{ mi}$$

Obviously there will not be 100% conversion of the beta energy to light nor 100% efficiency of light emission from the lighting fixtures; however, with reasonable estimates for these effects, it appears highly probable that the lights containing 30 curies of ^{85}Kr can be acquired at a distance of 1 to 5 miles. The above estimate for photopic acquisition is in good agreement with the distance observed in the tests at Andrews Air Force Base.

SECTION III

MEASUREMENT OF LIGHT OUTPUT

Based upon the reports of tests conducted in April 1979 at Andrews Air Force Base, lights produced under a DOE-funded program at Battelle Columbus Laboratory and American Atomics displayed visibility characteristics that were promising as runway marker lights. Since the FY 1980 program plan was to improve the light output when compared with the Battelle lights, measurement methods were designed to provide a simple comparison of the Battelle lights with the ORNL developments.

No attempt was made to analyze the spectral qualities of the lights.

A light tight chamber (FIGURE 3) was constructed containing a photodiode attached to the removable top. Current produced in the photodiode was measured as an index of light intensity. A yellow-green phosphor was used in the Battelle lights. The ORNL lights used yellow-green phosphor in three of the lights, blue in three lights, and red in two lights.

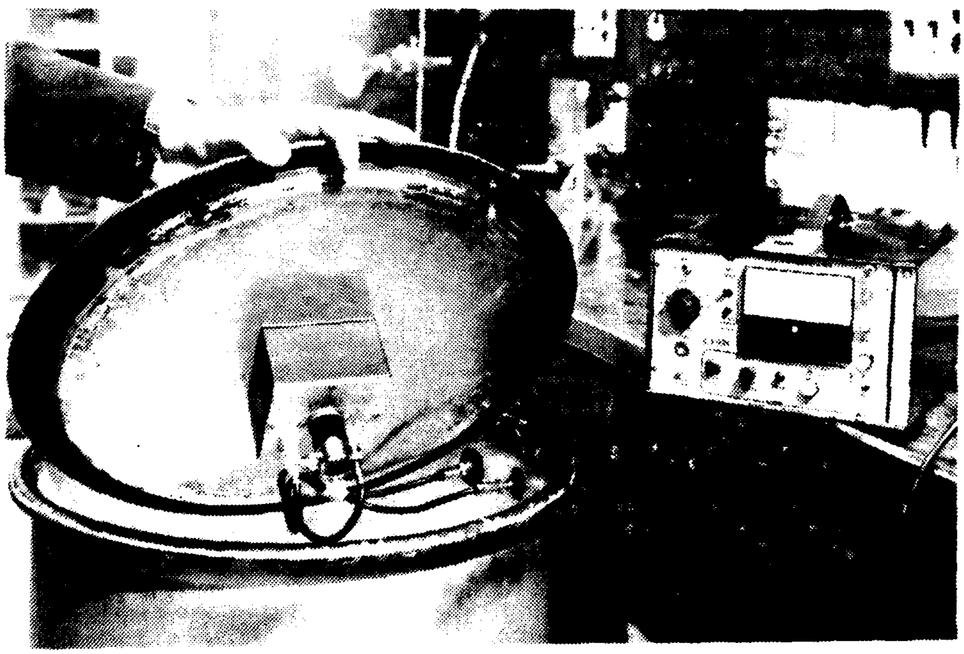

Figure 3. Light Chamber Used to Make Relative Light Intensities from Krypton-85 Light Sources

Assuming an index of 100 for the Battelle lights tested in 1979, a comparison with ORNL lights is as follows:

Battelle	Yellow-green	100
ORNL	Yellow-green	266
ORNL	Blue	288

These values were normalized to per curie of ^{85}Kr available to act on the phosphors.

The Battelle lights reportedly lost approximately 35% of their light output after one year due to causes other than decay of the ^{85}Kr. One explanation of this loss in efficiency is radiation damage on the phosphor, source window, or darkening of the adhesive used to attach the phosphor to the bottom of the source chamber. Since the Battelle light sources are brass chambers with phosphors in the bottom and a sealed sapphire window on top, contamination of the phosphor with trace metals could cause a depreciation in the light output of the phosphor.

We did not observe a decrease in light output after 3 months from the all quartz system used in the ORNL lights other than that accounted for by decay of the ^{85}Kr (10.3 y half-life).

If, however, we assume a similar loss of output from the ORNL lights (35%) after one year, the relative light output per curie of ^{85}Kr becomes:

Battelle	Yellow-green	100
ORNL	Yellow-green	172
ORNL	Blue	187

LIGHT SOURCE DESIGN

The total light output from a radionuclide gas-filled light source is dependent upon the efficiency one can design into the system relative to utilization of beta particles emitted by the radionuclide. Therefore, design becomes a critical factor. The range of the beta particle in a zinc sulfide phosphor is approximately 0.61 mm, which sets an upper limit on the phosphor thickness. To obtain a high degree of beta absorption the coatings thickness must be opaque to light produced within the coating. One method to overcome this difficulty is to place the transparent ^{85}Kr gas between the light source window and the phosphor. Using this system one could in principle utilize about 50% of the beta particles emitted for production of light. The other 50% would be lost to the window of the source. Pyrex glass and ordinary quartz darken when exposed to gamma rays emitted by ^{85}Kr. Very high purity quartz (Supersil) is sufficiently resistant to darkening by radiation to be useful in preparing the envelope to contain ^{85}Kr and the phosphor. A possible improvement in efficiency is to use granules of phosphor that are large enough to provide an extended surface for light emission. While light produced inside the granules would be lost, there would be a gain in the overall absorption of beta particles emitted by the ^{85}Kr isotope. Granules were prepared by two methods. In one case particles of quartz were coated with phosphor, and in the second the phosphor was mixed with adhesive and extruded through 0.35 mm holes, dried, and broken into approximately 0.35 mm lengths. The second method was used because it solved the problem of non-uniform coating of phosphor on the quartz granules. These granules were loaded into the quartz envelope and the entire assembly heated to remove moisture. In practice, the use of granules worked well and because the quartz tubes could be uniformly filled the method was selected for the eight lights prepared under the FY 1980 program.

The internal void volume was determined by evacuating the envelope and backfilling with air to a measured pressure from a known volume of air contained at a known temperature. Changes in the pressure of the standard air volume provides information needed to calculate the void volume of the light source.

$$V_2 = \frac{P_1 V_1}{P_2} ,$$

where

V_2 = volume to be determined, cm^3,

V_1 = known volume, cm^3,

P_1 = pressure in known volume, cm of Hg, and

P_2 = measured pressure, cm of Hg .

After the volume had been determined the phosphor-filled quartz tube was evacuated and 10 curies of ^{85}Kr were introduced into the tube and frozen to a small volume in a liquid nitrogen bath. The quartz tube was then sealed with a propane-oxygen flame and leak tested by immersion in water and observing for bubbles. Very small leaks were determined by soaking the light source in water for 16 hr (overnight) and testing the water for radioactivity.

SHIELD AND LIGHT PIPE

The reflector was machined from brass and nickel plated on the inner surface (FIGURE 4). The space between the outer surface of the reflector and the hemisphere holding the quartz light was filled with lead (3/4 in.) to provide for shielding of the gamma ray emitted by ^{85}Kr (0.514 Mev, 0.41% yield). While the gamma ray yield from ^{85}Kr is low, shielding is required to reduce the radiation from the sources to an acceptable limit (<10 mrem/hr at 1 meter). The quartz light source was shock mounted in the shield using silastic adhesive rubber and polyurethane sponge cusions. The shield was covered with a 6-in.-diam by 14-in.-long light pipe to transmit the light from the reflector and shield to a dome machined at the top of the light pipe where the light is emitted.

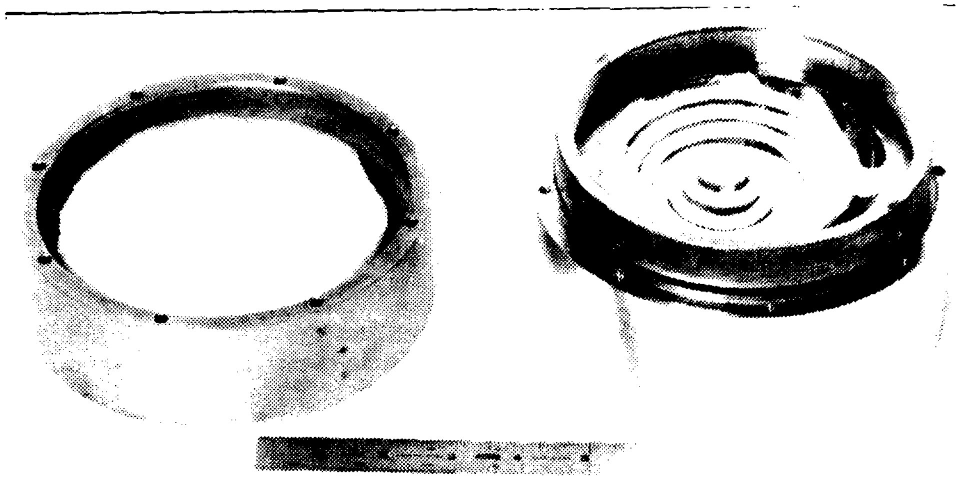

Figure 4. Krypton-85 Light Source in Reflector

Figure 5 is a photo of the complete assembly.

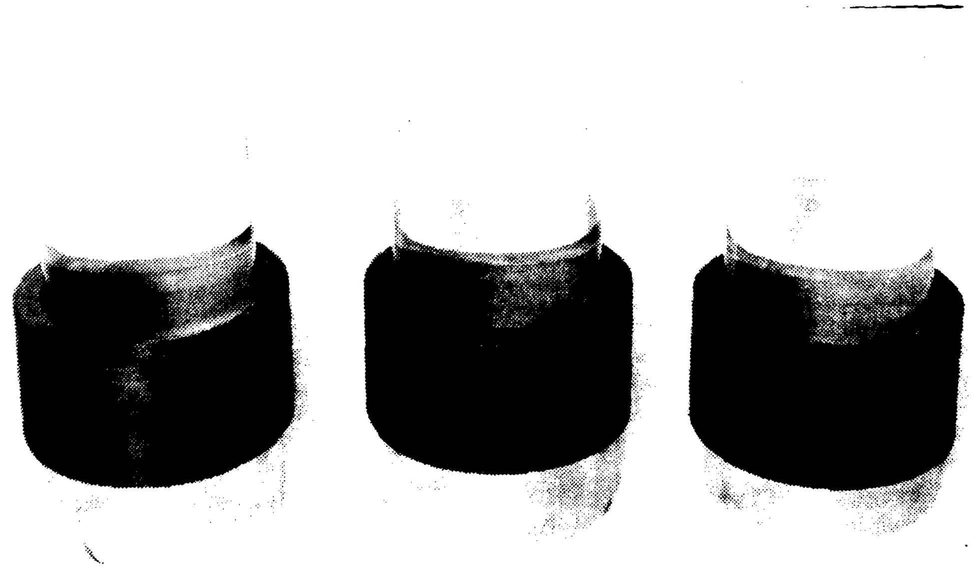

Figure 5. Complete Assembly of Three Krypton-85 Lights

HEALTH AND SAFETY

Evaluation of the health and safety consequences of accidental release of ^{85}Kr from ^{85}Kr-powered light sources was prepared for DOE by the NUS Corporation.[3] The evaluation assumed nine accident scenarios in which light sources are postulated to release ^{85}Kr to the environment.

In this evaluation the potential use of self-luminous lights powered by radioactive ^{85}Kr as taxiway and runway marker lights at airfields is discussed. Several accident scenarios,[4] especially those which might be unique to airfield operations, are discussed and the damage to the lights is estimated. Immersion doses to individual humans from possible release of ^{85}Kr from the damaged lights is computed assuming a maximum release of 30 curies per light and using a dispersion and dose calculation model developed by the NUS Corporation.[3,5]

A total of nine accident scenarios in which damage could be inflicted to the light fixtures are identified. Storage and handling operations, surface transportation accidents,[6] general purpose vehicle accidents, special purpose vehicle accidents, and normal weathering and corrosion of the lights on the runway-taxiway are those cases in which one to four light fixtures may be damaged. Air transportation accidents such as crash of a helicopter carrying a cargo of lights would involve damage of up to 100 light fixtures. If the helicopter runs out of fuel, fire may not occur, but if it crashes in bad weather with some fuel in its tank, the ^{85}Kr released will rise with the buoyant plume[7] and disperse into the ambient air. The last scenario considered is crash-landing of a plane on the runway or taxiway damaging up to 10 light fixtures. In this accident, two possible cases, plane catching or not catching fire are considered.

---

[3]NUS Corporation. "Overall Safety Manual," Vol. 2, Technical Models, (Prepared for the U.S. Atomic Energy Commission, June 1975).

[4]Philip C. Holden. "Worst-Case Accident Scenarios for Use of ^{85}Kr Airfield Lighting Units." (Memo from USAF Tyndall AFB, Florida to Gary Bennett of the U.S. Department of Energy, April 23, 1980).

[5]<u>Meteorology and Atomic Energy</u>. (U.S. Atomic Energy Commission, Division of Technical Information, 1968).

[6]R. K. Clarke, J. T. Foley, W. F. Hartman, and D. W. Larson. "Severities of Transportation Accidents." (Sandia Laboratories, SLA-74-0001, August 1978).

[7]G. A. Briggs. "Plume Rise Predictions." (Oak Ridge, Tennessee, Air Resources Atmospheric Turbulence and Diffusion Laboratory, National Oceanic and Atmospheric Administration [NOAA] June, 1975).

Accident scenarios and immersion doses to individuals exposed to the ^{85}Kr gas released from the damaged lights in each of the accident scenarios are summarized in Table 1. The results indicate that persons involved in storage and handling operations of the light fixtures are more likely to be exposed to higher immersion doses of ^{85}Kr gas than persons involved in any other operational activity connected with airfields. Assuming that two light fixtures are damaged in each operational activity, an immersion dose of 1.15 rem from release of 60 curies (Table 1) is received by one or two occupational workers in the storage area. If the storage area is enclosed, the atmospheric dispersion conditions would be worse than those considered in this study, and the dose received could be twice as much, i.e., approximately 2 rem. Extremely small immersion doses are estimated when a helicopter carrying a cargo of 100 light fixtures crashes and catches fire. The ^{85}Kr as released from the damaged lights will rise with the buoyant plume and disperse into the ambient air well above the ground. Consequently, the highest dose of 27 millirem is obtained at a distance of approximately 30 meters from the burning helicopter. However, if the helicopter exhausts its fuel supply and crashes, a maximum immersion dose of approximately 830 millirem is obtained within 20 meters from the helicopter.

Immersion doses to persons on the airfield from surface vehicular accidents are less than 890 millirem and doses from normal weathering and corrosion of light fixtures are less than 260 millirem under adverse atmospheric dispersion conditions.

When a plane such as C-130 crash-lands on the runway-taxiway and damages up to 10 light fixtures, a maximum dose of 12 millirem is obtained within 50 meters downwind of the line of lights. If the plane catches fire, the ^{85}Kr gas released from some of the damaged lights will rise with the buoyant plume and the resulting immersion doses are extremely small compared to the no-fire case.

As stated earlier, the expected maximum immersion dose for occupational workers involved in storage and handling operations is approximately 1.15 rem (2.30 rem if the storage area is enclosed) for each operation. If a worker is involved in four (two, if the storage area is enclosed) such operations in a year, a maximum immersion dose of 4.6 rem will be received. This is still less than 5 rem prescribed by the National Council on Radiation Protection and Measurements Basic Radiation Protection Criteria NCRP Report No. 39. For persons operating general purpose and special purpose vehicles on ground and flying a helicopter with a cargo of krypton lights, the immersion dose exceeds 800 millirem per accident. Although this dose is higher than 500 millirem prescribed for general public by NCRP, the probability of occurrence of such accidents is extremely small.

TABLE 1. IMMERSION DOSES RESULTING FROM VARIOUS ACCIDENT SCENARIOS

Accident Scenario	Expected Number of Damaged Light Fixtures and their Location	Expected Total Release of ^{85}Kr from the Light Fixtures (Ci)	Expected Immersion Dose Downwind of the Light Fixtures (rem) Stability Class/(wind speed, msec^{-1})				Remarks
			F/(2)	E/(3)	D/(5)	B/(3)	
a. Breakage in storage and handling operations	2 at a point	60	1.15	5.79×10^{-1}	3.10×10^{-1}	2.09×10^{-1}	Dose to persons at a downwind distance of less than one meter from the light.
b. Surface Transportation Accidents	4 in a line	120	8.85×10^{-1}	4.26×10^{-1}	2.12×10^{-1}	1.26×10^{-1}	Dose to persons downwind of the four damaged lights lying along a line.
c. General Purpose Vehicle Accidents							
a. Fixture lying on the ground	1 at a point	30	5.75×10^{-1}	2.90×10^{-1}	1.55×10^{-1}	1.04×10^{-1}	Dose to persons at a downwind distance of less than one meter from the damaged lights.
b. Fixture carried in the Vehicle	1 at a point	30	5.75×10^{-1}	2.90×10^{-1}	1.55×10^{-1}	1.04×10^{-1}	
d. Special Purpose Vehicle Accidents Snow Plow	4 in a line	120	8.85×10^{-1}	4.26×10^{-1}	2.12×10^{-1}	1.26×10^{-1}	Dose to persons downwind of the four damaged lights lying along a line.
e. *Normal Weathering and Corrosion*	*2 in a line*	*20*	2.52×10^{-1}	1.24×10^{-1}	6.41×10^{-2}	3.98×10^{-2}	Dose to persons downwind of the two damaged lights lying along a line.
f. Helicopter crash-No Fire	100 at a point	3000	8.28×10^{-1}	4.23×10^{-1}	2.10×10^{-1}	2.59×10^{-1}	Dose to persons within or at the edge of the cloud (20 m from the helicopter) in the downwind direction.
g. Helicopter crash-Fire	100 at a point	3000	1.62×10^{-4}	7.08×10^{-4}	2.7×10^{-2}	1.18×10^{-2}	Dose to persons of distances of 30 meters to 5 kilometers downwind of the burning helicopter.
h. Crash-landing of a Plane-No Fire	10 in a line	300	1.17×10^{-2}	5.31×10^{-3}	2.41×10^{-3}	1.93×10^{-3}	Dose to persons within 50 meters downwind of the crash-landed plane.
i. Crash-landing of a Plane-Fire	7 in a line	210	8.94×10^{-3}	4.17×10^{-3}	1.92×10^{-3}	1.69×10^{-3}	Dose to persons downwind of the seven damaged lights not caught in the fire.
	3 at a point	90	5.72×10^{-6}	2.12×10^{-5}	1.36×10^{-9}	1.54×10^{-10}	Dose to persons located 100 m meters to 5 kilometers downwind of the burning plane.

SECTION IV

CONCLUSION

From the discussion presented above, it can be concluded that the use of krypton-powered lights as runway and taxiway lights would not pose a serious health or safety hazard to either occupational workers or to general public.

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